# Using tracker for jet energy correction

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➢ **Calorimeter consists of two compartments and both has different response to electrons and hadrons**

➢ **Jets have both hadronic (charged and neutrals) and e/γ components.**

*Method description:*

**Jet energy=Response_charged+Response (e/γ)+Response (neutral)**

◆ **Change response of charged hadron of jet to energy from Tracker**

◆ **Add tracks out of reco cone (A.Nikitenko)**

**Jet energy=E_TRACKER+Response (e/γ+neutral)_ECAL+**

**Response (neutral)_HCAL**

**Response (R(ECAL), R(HCAL) is calculated inside cone around jet axis using standard procedure and with default coefficients.**

**Expected response was calculated in different ways:**

**e/π technique (1), library of responses(2), matched cluster(3)**

**Remark: e/π technique, energy flow objects = matched cluster (D.Green)**

# *Condition: Single jet  (no pile−up, no underlying event)*

✏  **QCD dijet events  with Pthat 20−120 GeV are generated with PYTHIA 6.15x**

*Only jet particles in cone 0.5 on generator level are propagated through cmsim 121/cmsim 123.*

✏  **Parameters of algorithm:**
**(e/h)_(ECAL), (e/h)_HCAL, E_ECAL/E_HCAL for charged particles− used in algorithm were taken  from test−beam  data where HCAL was calibrated to electrons.**

## *Short description of procedure:*

◆ **Jet is found using only calorimeter information in cone R (R=0.5)**

◆ **Energy of charged hadrons of jet is taken from Tracker**

◆ **Summarized expected response of charged hadrons is subtracted from Response_ECAL and Response_HCAL of jet**

*Response (e/γ+neutral)_ECAL=Response_ECAL−Response(charged)_ECAL*

*Response (neutral)_HCAL=Response_HCAL−Response(charged)_HCAL*

**Jet energy=E_TRACKER+Response (e/γ+neutral)_ECAL+**
**Response (neutral)_HCAL**

**Expected response calculation:**

**Version 1: e/π technique**
**Version 2: library of responses**
**Version 3: matched cluster+(1 or 2)**

◆ **Charged particles out of reco cone were added**

# e/π technique (Version 1)

✎      For each interacted charged particle **Dan Green's procedure** to find **response of this particle in ECAL and** HCAL is used to calculate mean response in calorimeters.

**For each charged the ratio of responses to electrons and pions is calculated:**

e/π(ECAL)=e/h(ECAL)/(1+(e/h(ECAL)−1)*F0_ECAL
e/π(HCAL)=e/h(HCAL)/(1+(e/h(HCAL)−1)*F0_HCAL
          F0_ECAL=0.11*log(E_ECAL)
          F0_HCAL=0.11*log(E_HCAL)

F0_ECAL,HCAL−electromagnetic fraction of hadronic shower.
E_ECAL, E_HCAL − energy deposited in ECAL,HCAL e/h is obtained by fitting test−beam data.

✎      For each charged particle **E3x3 around entry point** is used to determine if particle interacts in ECAL or not.

*How deposited energy E_ECAL, E_HCAL are evaluated:*

**Particle interacted in ECAL**

  E_ECAL=**0.4**\*Etracker (test beam, talk of J.Freeman)
  E_HCAL=**0.6**\*Etracker

**Particle does not interact in ECAL**

  E_ECAL=E_MIP (energy from EM cluster)
  E_HCAL=Etracker−E_MIP

*Response from charged particles is calculated.*

**Particle interacted in ECAL**

  R_ECAL=E_ECAL/(e/π)(ECAL)
  R_HCAL=E_HCAL/(e/π)(HCAL)

**e/h(ECAL)=1.6**
**e/h(HCAL)=1.39**

**Particle does not interact in ECAL**

  R_ECAL=E_MIP
  R_HCAL=E_HCAL/(e/π)(HCAL)

# Library of responses (Version 2)

*Mean responses were calculated using pion samples of different energies for the cases when pion is interacted in ECAL or not*
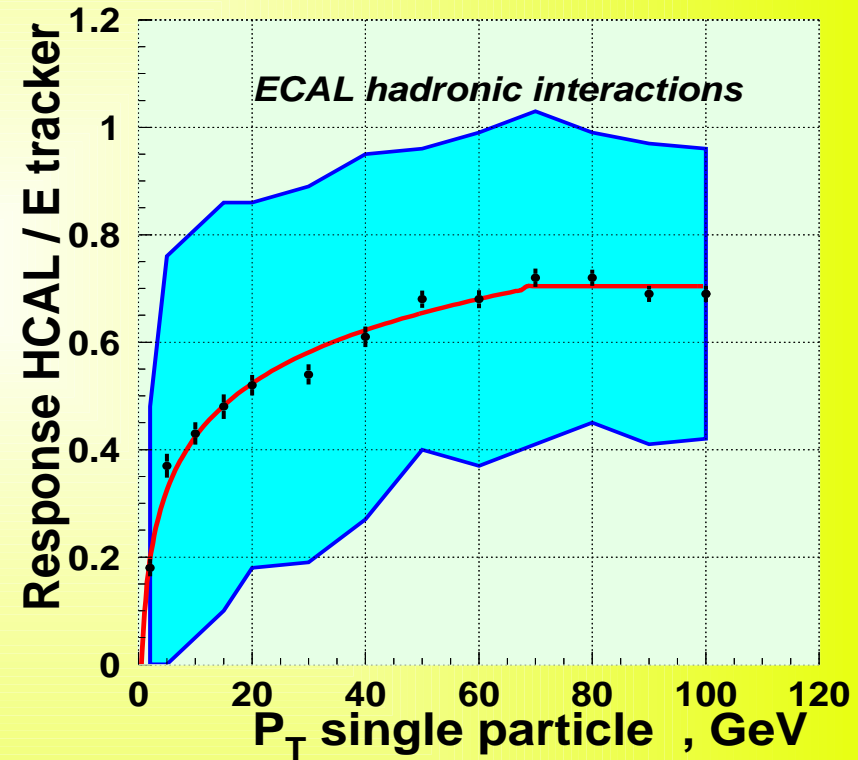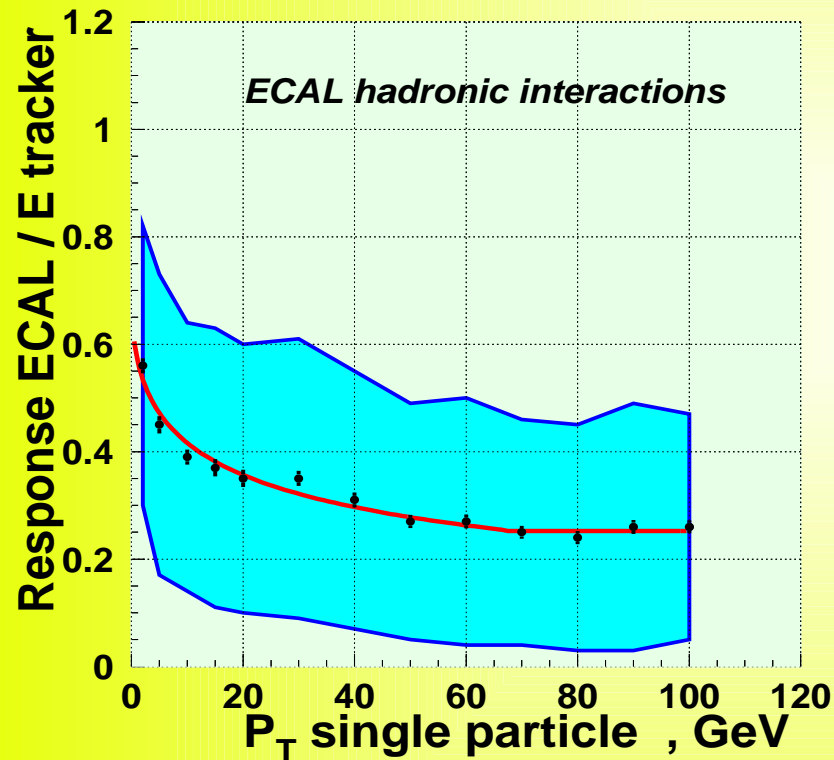
# Matched cluster+library of responses (Version3)

✎ For each charhed particle (in reco cone) 3x3 ECAL crystal matrix was constructed around entry point. Cluster building starts from maximal track.

✎ For each charged particle (in reco cone) 3x3 HCAL tower matrix was constructed around entry point.

✎ Energy response in ECAL+HCAL cluster (3x3 crystal+ 3x3 tower) was compared with Etracker for this particle

✎ Energy of cluster matched with track was changed to the energy of particle in tracker.

Cluster is matched with track if: $-\sigma < E_{tracker} - E_{cluster} < 2\sigma$

$$\sigma / E = 100\% / sqrt(E) \oplus 5\%$$

✎ For tracks non−matched cluster expected response subtraction procedure was applied (1,2).

✎ Charged particles out of reco cone were added

## *Fortran:*

✎   **1) The entry point of charged particles to ECAL was taken from generation on CMSIM level.
2) Matrix 3x3 crystals and 3x3 towers is built around entry point**

   <span style="color:red">**No reconstruction algorithms in tracker were used**</span>
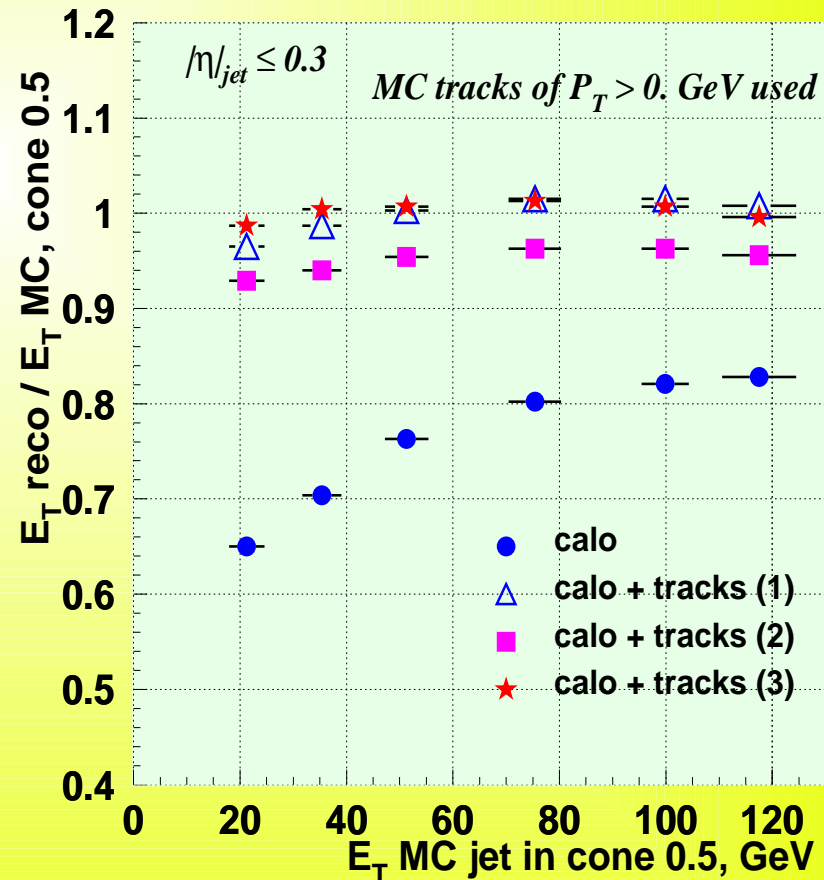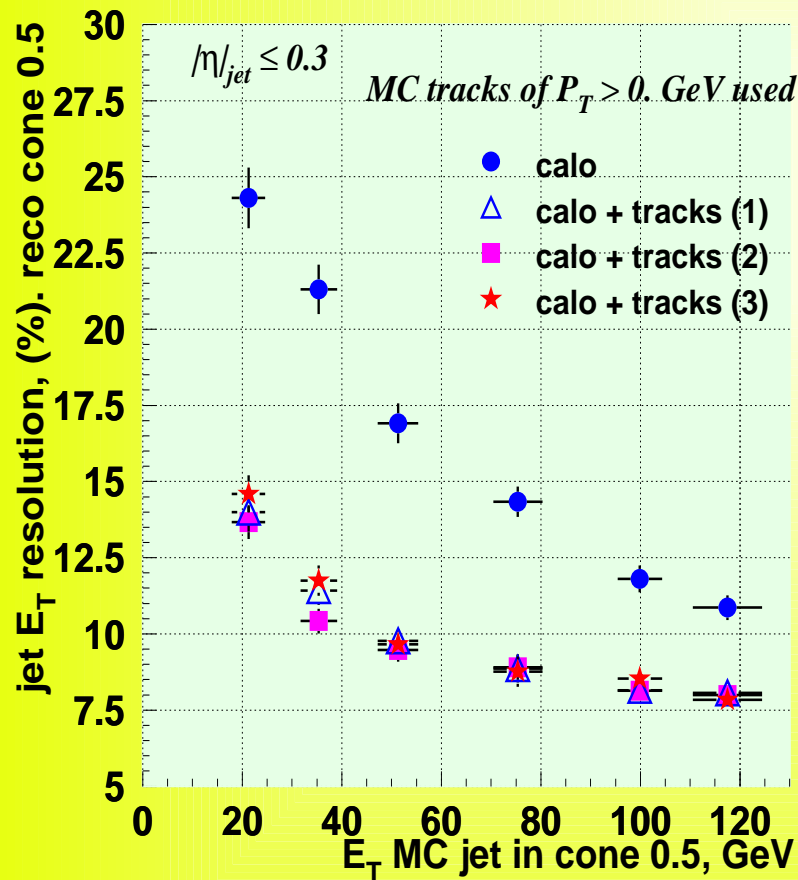
## *ORCA531:*

✎   **1) Reconstructed tracks are found with TrackReconstructor
(<span style="color:red">CombinatorialTrackFinder</span>) and from the last found rhit track
is propagated to ECAL with GeaneWrapper.
2) MC tracks were propagated to ECAL with GtfPropagator and
GeaneWrapper
3) Tower with impact of reconstructed track is used (5x5 crystals
and it is not centered around entry point). To apply the same
procedure as in FORTRAN one have to get CellID of crystal
with impact of reconstructed track.**

# FORTRAN

**Resolution and mean ETrec/ETgen for different MC jet energy.** Window algorithm and algorithm with tracker information. Three options are used for calculating expected response: **e/π technique (calo+tracks(1))**, **library of responses (calo+tracks (2))**, **matched clusters+library of responses (calo+tracks(3))**
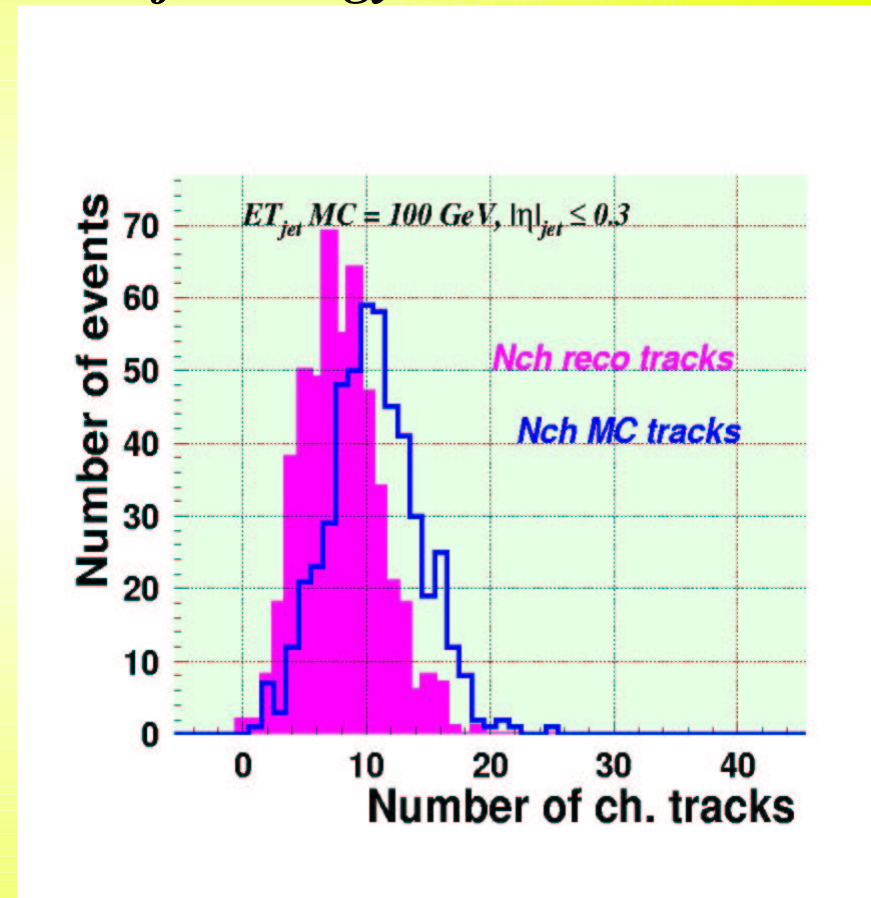
## ORCA531

**Mean number of MC and reconstructed tracks for different MC jet energy**
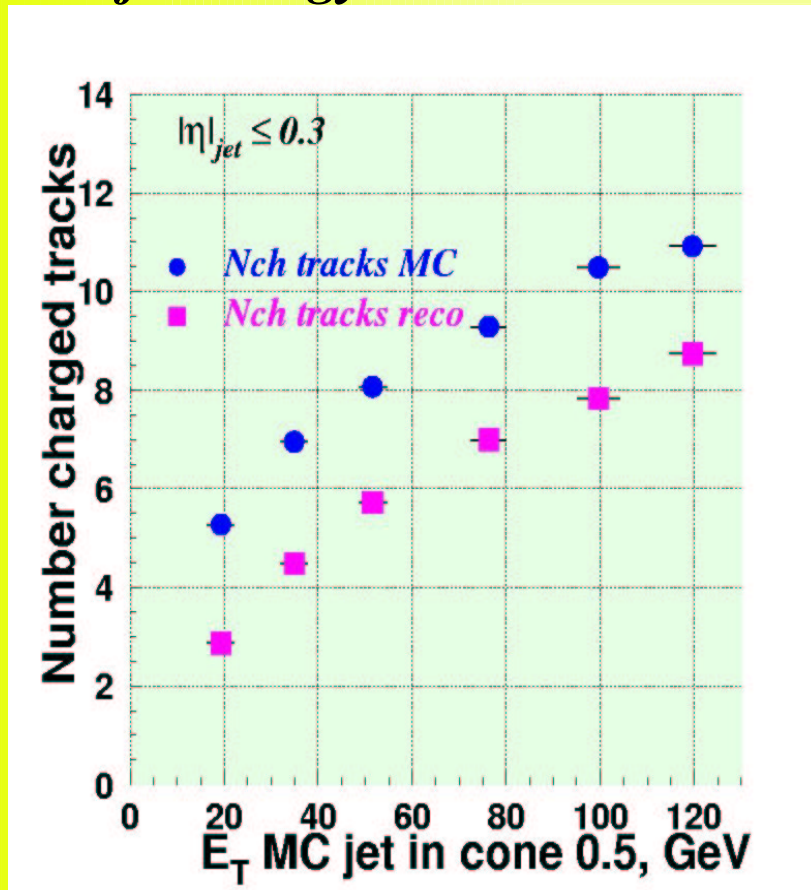
**Distribution on number of MC and reconstructed tracks for MC jet energy 100GeV**



**For 20 GeV jets only ~50% of tracks is reconstructed. For 100 GeV jets ~75% of tracks is reconstructed.**
**MC tracks included all charged tracks from jet.**

# Dependance of $E_T$ reco/$E_T$ MC on $E_T$ MC jet

**FORTRAN:** *e/π technique+out−of−cone(1)*
*library of responses+out−of−cone (2)*
*matched clusters+*
*library of responses + out−of−cone (3)*

**ORCA:** *only e/π technique+*
*out−of−cone*



*Open blue circles − only tracks out of cone are added to calo response.*
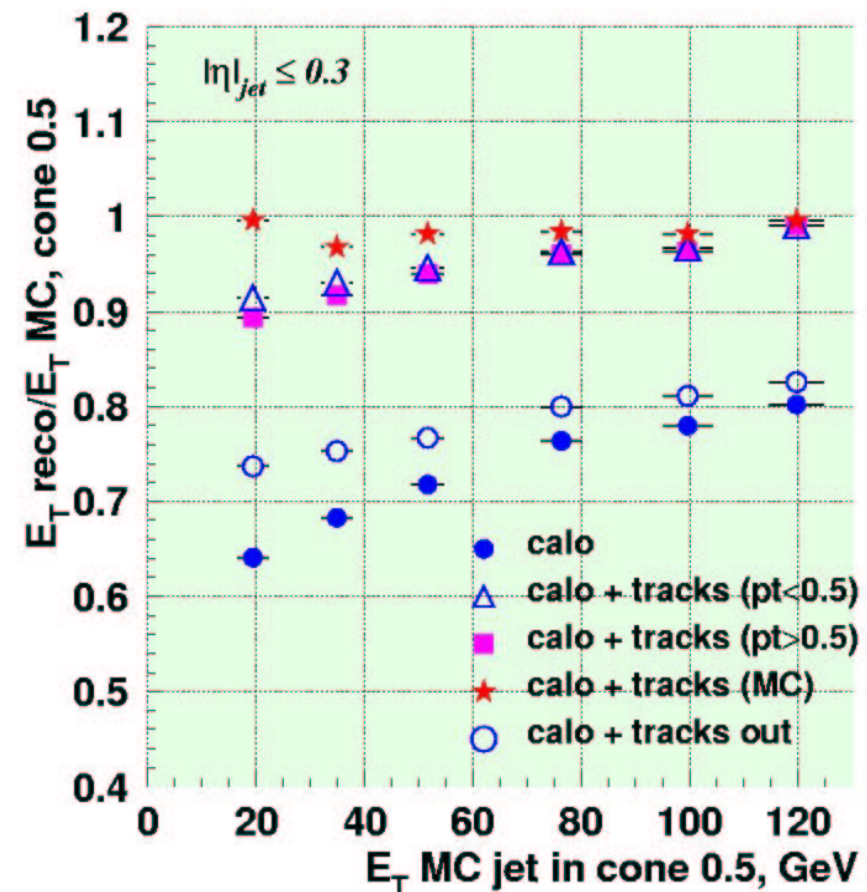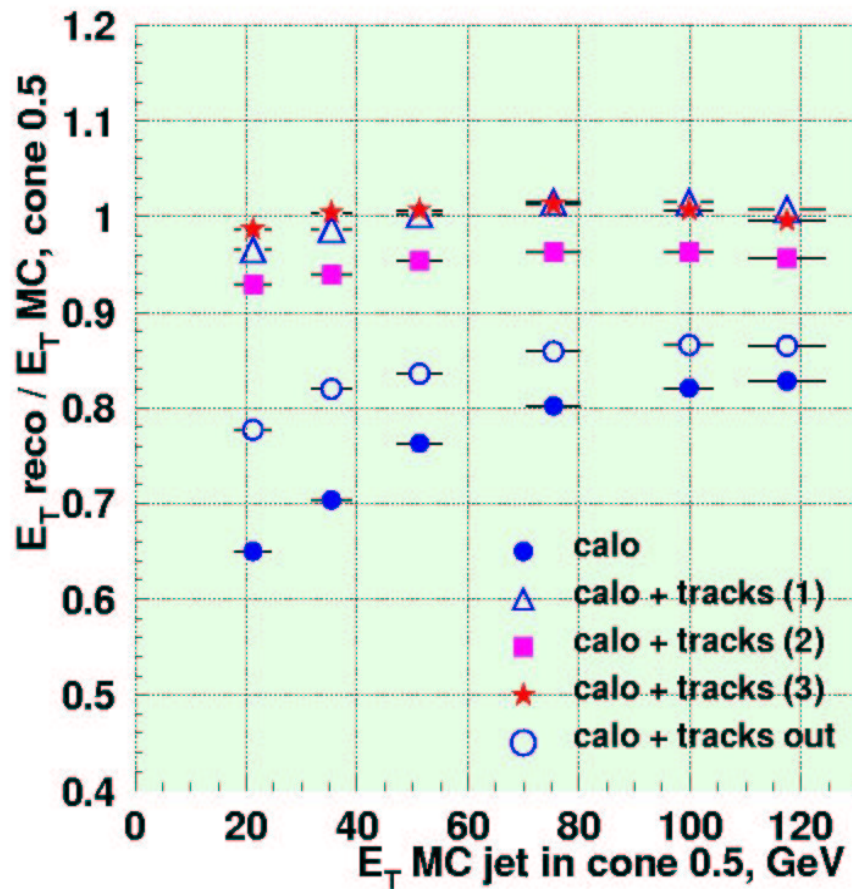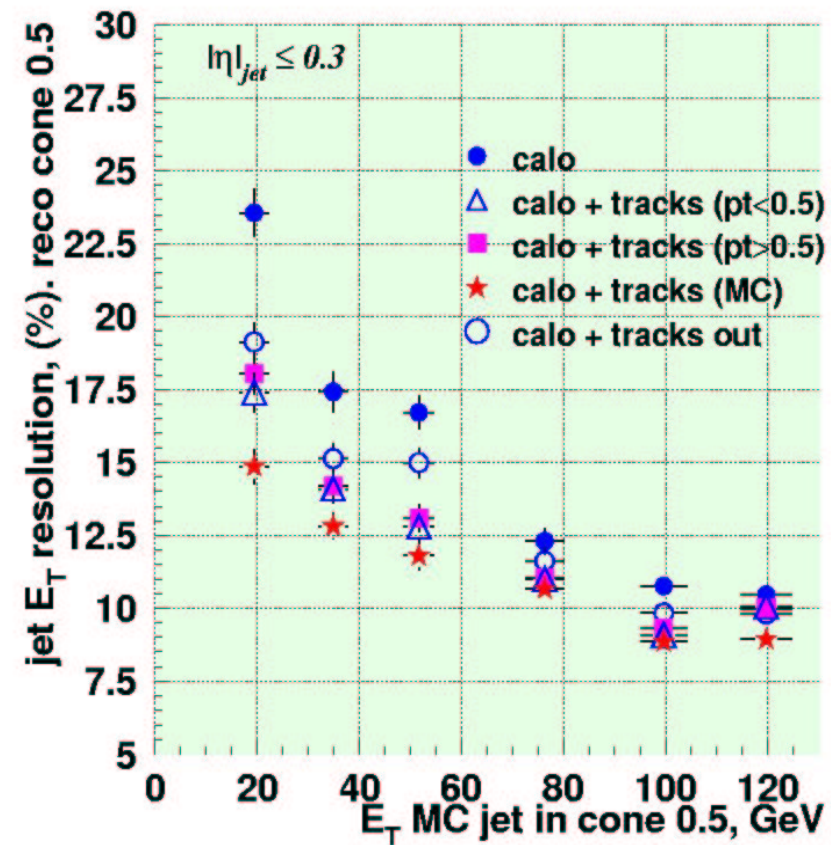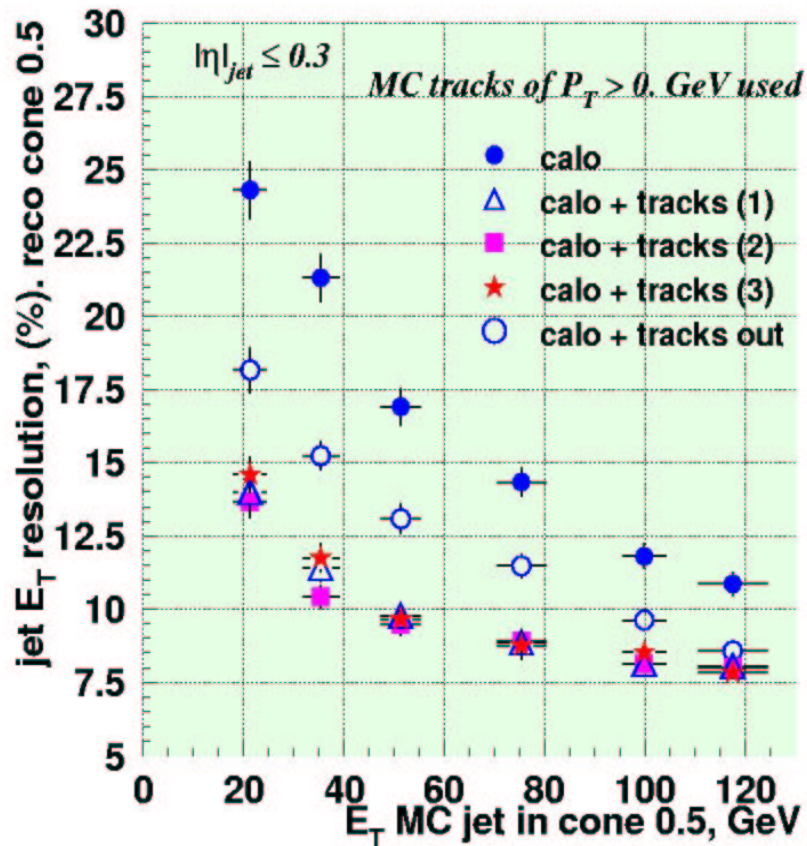
# Dependance of resolution on $E_T$ MC jet

**FORTRAN:** *e/π technique+out−of−cone(1)*
   *library of responses+out−of−cone (2)*
   *matched clusters+*
   *library of responses + out−of−cone (3)*

**ORCA:** *only e/π technique+*
   *out−of−cone*

# *Summary*

We considered  procedure of using tracker information :
change of response of charged hadron of jet to energy from Tracker


FORTRAN:
  Three options for response calculation were used:
  e/π technique (version 1), library of responses (version 2) ,
  matched clusters+library of responses (version 3)

  All versions gives the same improvement for energy resolution:
    from 1.7 times at 20 GeV jets to 1.5 times for 100 GeV jets
    for 20 GeV: from **24% to 14%**
    for  100 GeV: from **12% to 8%**

    *The best linearity is achieved with version 3:*
    matched clusters+library of responses+ tracks out of cone

  *However it is not excluded the possibility to have the same results with
  two other options by tunning parametrizations.*

**ORCA:**

*Expected response is calculated using* **e/π technique.**

*Three different cases are considered:*
*1) Tracks are reconstructed with CombinatorialTrackFinder. It has limitation on Pt of track (Particles with Pt>0.5GeV are reconstructed).*
*2) Tracks are reconstructed with CombinatorialTrackFinder and MC tracks with Pt<0.5 GeV/c are added.*
*3) MC tracks are propagated from the vertex to ECAL surface.*

*1) and 2) cases give appoximately the same results both for linearity and resolution which is worse than for FORTRAN version.*
*It collects 89% (91%) of jet energy for 20 GeV jets and ~99% (99%) for 120 GeV*
*Resolution improves from 23.6% to 18 % (17.4%) for 20 GeV jets and from 10.8% to 9.3% (9.1%) for 100 GeV jets.*

*For the 3) case linearity is almost completely restored and resolution is improved from 23.6% to 14.9% for 20 GeV jets and from 10.8% to 8.9% which is comparable to results obtained with FORTRAN code.*

# FORTRAN vs ORCA

The case 3) is the most closest to FORTRAN version but in FORTRAN impacts on ECAL surface are taken and in ORCA MC tracks are propagated from vertex.

For case 1) and 2) we have in addition the efficiency of reconstruction in Tracker which is different for tracks from jets of different MC energy.

For all three cases one has to have CellID for impact of reconstructed/propagated track on ECAL surface in order to apply completely the same procedure as in FORTRAN.

The absense of easy procedure to get CelID is now the limitation for coding the library of responses and matching clusters methods.